Chapter 3: Heating System Measures

3.1 Heating Systems

This chapter covers improvements to heating systems. The improvements include the replacement or the modification and repair of the appliance. Complete combustion safety testing for all systems and steady-state efficiency (SSE) testing on gas and oil heating systems. All heating system work is completed by qualified professionals.

3.2 General Heating System Replacement

Observe the following standards for heating system replacement:

1. Install heating systems in accordance with manufacturer's instructions and applicable State and local codes.
2. Use existing distribution system and fuel supply line (when possible).
3. Properly remove and dispose of existing unit.
4. Provide an owner's manual with heating system replacements.
5. New heating systems require a dedicated electrical circuit rated or fused to match the amperage of the system's requirements for overcurrent protection. Condensate pumps are allowed to be on the same circuit.
6. Verify and make adjustments, if necessary, so that flue-gas oxygen, stack temperature, and carbon-monoxide levels are within manufacturer's specifications. If manufacturer's specifications are not available, refer to *Table 3-2* or *Table 3-5*.
7. Install a condensate pump where needed to reach an appropriate drain. See *Condensate Removal in Chapter 3 - Section 3.8.2* for more information about condensate pumps.
8. Install condensate tubing or piping to reach an appropriate drain.
9. Seal openings in chimneys where natural-draft or fan assisted appliances are eliminated. Indicate with a written notice on the chimney, where sealed, that the chimney is no longer functional.
10. Provide in-home operation and maintenance instructions, as well as a review of safety precautions to the customer.
11. Affix a tag, displayed prominently, that identifies who the customer should call for service to the heating unit. The tag information shall contain the name, address, and telephone number of the service organization.

3.3 Forced-Air Furnace Replacement

Observe the following standards specific to forced-air furnace installation:

1. Verify that the temperature rise is within manufacture's limits as indicated on the furnace label.
2. Set fan control for optimal efficiency without negatively impacting occupant comfort.
3. Perform all required tests and document results.
4. Seal holes through the jacket of the air handler with mastic or foil tape.

3.4 Forced-Air Furnace Air Distribution

Forced-air duct systems present opportunities for saving energy in homes. Ducts waste energy through air leaks, lack of insulation, and airflow problems when they pass through unconditioned spaces. This section addresses these forced-air distribution problems.

3.4.1 Duct System Modification

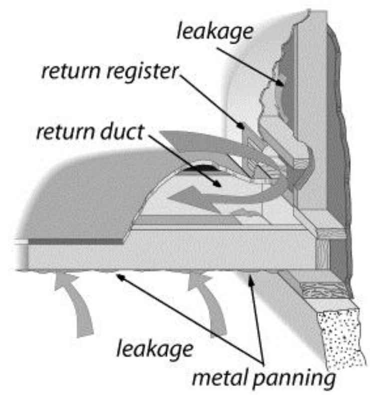
1. Add return or supply ductwork as part of furnace replacement to improve air distribution to an acceptable level or to establish an acceptable value for temperature rise (supply temperature minus return temperature). Add ductwork to address client comfort or duct-induced pressure issues only with agency approval.
2. Do not add supply registers to the combustion-appliance zone (CAZ) unless it is an intentionally heated part of the home. Consult with the customer about removing existing grills in the CAZ. If grills are removed, document the customer consultation in the file.
3. Mechanically fasten supply and return ductwork with screws. Seal the ductwork to the furnace cabinet with mastic and fabric mesh tape, or other UL 181-approved material, to form an essentially airtight connection on all sides of these important joints.
4. Do not install new ductwork in unconditioned spaces unless absolutely necessary. If ducts are located in unconditioned spaces, seal the joints and insulate the ducts as specified.
5. Connect new ducts to the existing distribution. Install a balancing damper in each new branch supply duct. Install registers to terminate each new supply or return branch duct.

3.4.2 Duct Leakage

Leaky ductwork poses two problems: it impacts the occupants' health and safety, and it also affects the home's energy consumption.

Seal all ductwork that runs outside the dwelling's heated envelope. These duct leaks waste energy, and they also introduce health and safety hazards. For example, leaky supply ducts can introduce excessive moisture into unheated spaces, and they also depressurize the home. When return ducts leak in unheated spaces, they may serve to draw pollutants into the distribution stream of air.

In the CAZ, return-ductwork leakage causes depressurization and increases the likelihood that natural-draft appliances will backdraft. Supply-side leaks in the CAZ are less likely to cause backdrafts; rather, they may aid the appliances' natural draft by adding pressure to the room.



Panned floor joists: These return ducts are often very leaky and may require removing the panning to seal the cavity.

Duct leakage that occurs inside the heated envelope is less likely to contribute to increased energy consumption. The leakage, however, may lead to an unintentional and uneven distribution of heat throughout the home, with less hot air distributing to the rooms where the occupants spend much of their time.

Follow these instructions when sealing ductwork:

1. Seal all ducts that are located outside the thermal boundary.
2. Seal the connection between the furnace and the supply plenum, as well as the connection between the furnace and the return drop.
3. Seal all gross holes in the supply and return ductwork.
4. Consider temporarily removing joist panning along the building's exterior, to investigate for air infiltration into the duct system. Replace joist panning when investigation is complete.
5. After completing Steps 1-4, follow the diagnostic workbook to guide further sealing.

Materials for Duct Air-sealing

Duct mastic is the preferred duct-sealing material because of its superior durability and adhesion. Apply mastic at least 1/16-inch thick and use reinforcing mesh or UL 181-approved tape for all joints wider than 1/8-inch or joints that may experience some movement. Silicone or siliconized acrylic-latex caulk is acceptable for sealing wood-to-wood joints in panned joist spaces that function as return ducts.

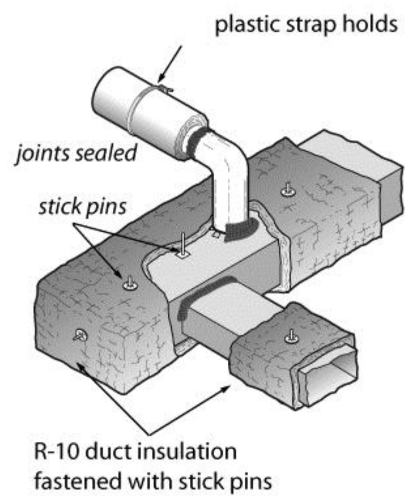
Joints should rely on mechanical fasteners to prevent joint movement or separation. Tape alone will not hold a joint together, and it will not resist the force of compacted insulation or joint movement. Aluminum foil tape or cloth duct tape are not good materials for duct sealing, because their adhesive often fails after a short time

3.4.3 Duct Insulation

Insulate forced-air ducts that run through unconditioned areas with a minimum of R-10 foil-faced duct insulation. Ducts may be insulated with two-part foam products that meet the federal specification for duct insulation.

Do not apply duct insulation to ducts that will be surrounded by R-10 or more of loose-fill insulation. Before installing the loose-fill insulation, make sure to seal these ducts.

Don't insulate ducts that run through conditioned areas unless they cause overheating in winter or condensation in summer.



Duct insulation: Forced air ducts, located in unheated areas, should be insulated to a minimum of R-10.

Follow these steps when installing duct insulation:

1. Perform necessary duct sealing before insulating ducts.
2. Insulate all exposed forced-air ducts, without significant areas of bare duct left un-insulated.
3. Fasten insulation mechanically, using stick pins, twine, plastic straps, or other appropriate materials. Tape the joints in the insulation to prevent air convection, and apply mastic over the tape to increase the tape's longevity.

3.4.4 Measuring System Airflow

Low airflow is a common problem in forced-air duct systems. The air flow significantly influences the temperature rise. Excessive air flow may cause customer-comfort issues. Insufficient air flow may cause short-cycling or, in severe cases, a cracked heat exchanger.

The most common causes are too-small supply ducts, inadequate or restricted return ducts, and dirty filters or coils. Table 3.1 shows recommended minimum air flow for various forced air systems. When air flow measures lower than what is calculated with the multiplier, the system is likely to have a temperature rise that is higher than that allowed by the manufacturer.

Table 3-1: Recommended Minimum Air Flow *(in CFM)*

Furnace size in kBtu	Natural Draft	Fan-Assisted Draft	Sealed Combustion
40	400	520	600
50	500	650	750
60	600	780	900
75	750	975	1,125
100	1,000	1,300	1,500
	Multiplier		
kBtu x	10	13	15
To calculate the minimum air flow for a furnace, multiply the input kBtu's by the multiplier for the type of furnace. (i.e 55 x 15 = 825 CFM)			

Preparing to Measure Airflow

Sophisticated test instruments are not necessary to discover that filters, air-conditioning coils (A-coils), or blowers are packed with dirt or that the branch duct to the master bedroom is disconnected. Diagnose these problems before measuring duct airflow. The following steps precede airflow measurements:

1. Ask the customer about comfort problems and temperature differences in various parts of the home.
2. Based on the customer's comments, look for disconnected or restricted ducts.
3. Inspect the filter(s), blower fan, and A-Coil for dirt. Clean them if necessary. If the A-coil isn't easily visible, a dirty blower fan is a fair indicator that the A-coil may also be dirty.

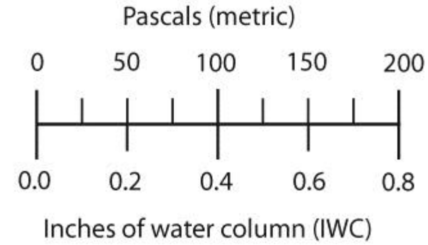
Flow-plate Method for Measuring System Airflow

The flow-plate meter is a plate with holes and sampling tubes that work in conjunction with a digital manometer to measure the velocity and static pressures inside the ductwork. The manometer then converts these values into an estimate of the distribution airflow.

The flow-plate meter will contain metering plates that can be configured to fit inside all standard-size filter slots. Whenever possible, make sure that the plate is not bigger than the return cutout in the furnace. See the instruction manual for the flow-plate meter for specific directions on its use.

Measuring External Static Pressure

External static pressure (ESP) is the difference between pressures in the supply and return ductwork. ESP is the airflow resistance that is caused by items external to the furnace cabinet. The ESP test can be used to identify existing ductwork issues such as insufficiently sized ductwork or obstructed cold air returns. Testing for ESP also allows for estimation of airflow if the furnace manufacturer's fan tables for static pressure and airflow are available.

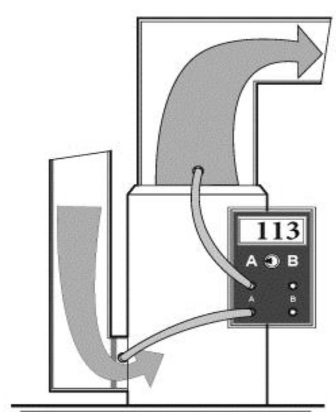


Pressure in two measurement systems: Technicians and engineers use both pascals (metric) and inches of water column (American) to measure duct pressures.

ESP equals the sum of the absolute values of the static pressures in the supply and return sides. For example, a supply-side static pressure of +30 pascals and a return-side static pressure of -80 pascals indicates an ESP of 110 pascals (80 + 30 = 110). The supply-side static pressure will always be a positive number, and the return-side static pressure will always be a negative number. The larger the ESP, the lower the airflow at a given fan speed.

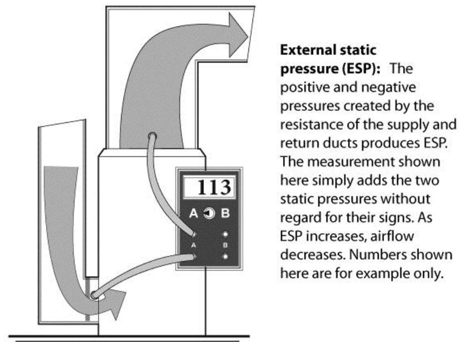
The ESP test requires a static-pressure probe, a pressure hose, and a digital manometer. Follow these steps to test the ESP of a forced-air heating system:

1. Install a clean furnace filter into the filter slot.
2. Drill one hole in the supply plenum, above the furnace cabinet and below the A-coil drain pan (if present). The hole must be large enough to accommodate a static-pressure probe.
3. Drill a second hole on the return side, at a location between the furnace filter and the air handler. Depending on the location of the filter slot, this hole may need to be drilled into the furnace cabinet. (Use existing opening already present in the furnace cabinet, rather than drilling a new one.)



Static pressure and temperature rise: Testing static pressure and temperature rise across the new furnace should verify that the duct system isn't restricted. The correct airflow, specified by the manufacturer, is necessary for high efficiency.

4. Set the digital manometer to “PR/PR” mode, and attach a pressure hose to the Channel A Input tap.
5. Attach the static-pressure probe to the hose. Insert the probe into each of the holes, and record the test result for each hole.
6. Add the absolute values of the two test results, treating each result as if it were a positive number. This sum is the ESP for the heating system.
7. The higher the ESP measurement the lower the airflow will be (assuming no change in the air handler’s speed setting). The manufacturers’ maximum recommended ESP is usually 0.50 IWC for standard air handlers. As ESP increases above 0.50 IWC, the likelihood of insufficient airflow increases. An exorbitant ESP may indicate the presence of constricted or insufficient ductwork, a plugged A-coil or furnace filter, or other distribution-system issues.



External static pressure (ESP): The positive and negative pressures created by the supply and return ducts produces ESP. The measurement shown here simply adds the two static pressures without regard for their signs. As ESP increases, airflow decreases. Numbers shown here are for example only.

External Static Pressure

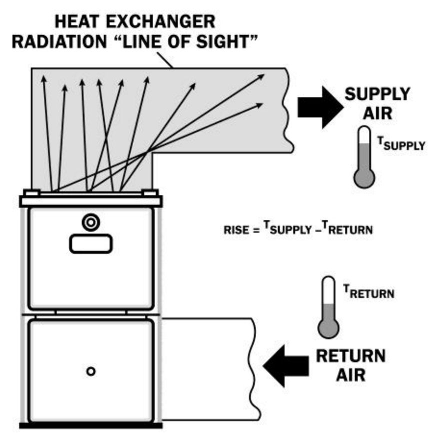
ESP (IWC)	0.3	0.4	0.5	0.6	0.7	0.8
CFM	995	945	895	840	760	670

Use the ESP test as a guide, along with client conversations and the airflow and temperature-rise tests, in determining whether the heating system has sufficient airflow.

3.4.5 Measuring Temperature Rise

Temperature rise is the temperature difference between the supplied air and the return air. This test is critical in determining if the furnace is set up and operating properly. Perform the test after the furnace has reached steady state and the duct work has heated up.

Measure the return temperature by inserting the thermometer in the return drop prior to the filter. Measure the supply temperature in a main duct as close to the plenum as possible without being in the line of sight of the heat exchanger. When there are multiple main ducts, measure the temperature in each branch and use the highest reading.



Temperature Rise Measurement

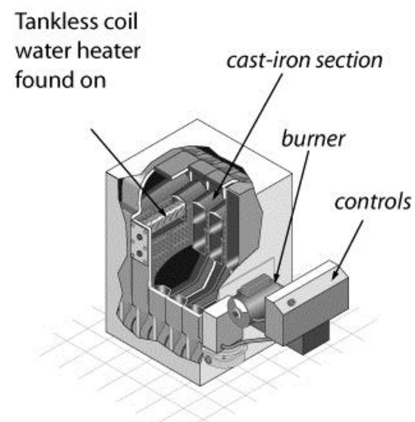
3.4.6 Filters

Observe the following standards related to furnace filter installation.

1. Supply the customer with furnace filters. Provide either:
    a. Six 1” - 2” replaceable filters (one of these is installed); or
    b. One washable filter (installed); or
    c. One deep-pleated filter (installed).
2. Confirm that filters are held firmly in place and provide complete coverage of the blower intake or the return register.
3. Ensure that filters are easy to replace.
4. Confirm that the heating system has a sealing filter cover, and install a new one if none exists. Construct the new filter-slot cover so that it can be removed easily and safely. Confirm that the filter is easy to access and replace. Magnetic filter covers are allowable only if they provide an adequate seal to the ductwork to prevent air leakage.

3.5 Boiler Replacement

Complete all tests on the Hot Water Boiler Replacement Check List and document results.



Cast-iron sectional boilers: The most common boiler type for residential application.

Follow these specifications when replacing boilers:

1. Flush the existing distribution system per manufacturer’s instructions or until the water runs clean and is free of sediment. With a zoned system, flush each zone separately.
2. Locate stop valves at accessible points in the supply and return pipe connections and as near to the boiler as is convenient and practical to permit draining the boiler without emptying the system.
3. Locate new zone valves near the boiler. Confirm that each zone has its own shut-off valve.
4. Install a pressure-relief valve (PRV) per manufacturer’s instructions. Confirm that the PRV is rated and sized correctly for the boiler BTU input and maximum operating pressure.
5. Install an automatic fill valve, if none is present.

6. The feed-water (inlet) side of the pressure-reducing feed valve shall have a backflow preventer, with a shut-off valve installed upstream from the backflow preventer; and the boiler (outlet) side of the pressure-reducing feed valve also shall have a shut-off valve, to allow for maintenance or replacement without draining the boiler system.
7. The backflow preventer shall have:
    a. A drain facing the floor.
    b. A pressure-reducing feed valve with either a purge valve or bypass piping with a shut-off valve.
8. The system shall have an adequately sized expansion tank. Install an expansion tank, or fill the existing expansion tank and the system to the correct level.
    a. If the existing tank is a pre-pressurized diaphragm type and the tank is older than 10 years, the expansion tank shall be replaced with a properly sized one.
9. Install the circulator pump near the downstream side of the expansion tank to prevent the suction side of the pump from depressurizing the piping, which can pull air into the piping.
10. Verify that return-water temperature is appropriate:
    a. For oil boilers, verify that return-water temperature is above 150° F.
    b. For non-condensing gas boilers, verify that return-water temperature is above 130° F, to prevent acidic condensation within the boiler.
11. Install piping bypasses, mixing valves, primary-secondary piping, or other strategies as necessary to prevent condensation.
12. For condensing boilers, install condensation-resistant venting with condensation drains designed into the venting system per the manufacturer's specifications.
13. Insulate all pipes on the circulating loop between the boiler and an indirect domestic water heater.
14. When installed on a floor below grade, a new boiler shall be installed above known flood levels and as high as practical to avoid damage in case of flooding.
15. Inspect chimney for deterioration and correct sizing. Repair and reline the chimney as necessary.
16. Install an electric vent damper where feasible for standard-efficiency boilers.

3.5.1 High-Efficiency (≥90%) Boilers

High-efficiency boilers often present significant energy-saving opportunities as compared with standard-efficiency boilers. Similar to ≥90% efficient furnaces, high-efficiency boilers cause water vapor in the exhaust gases to condense, which releases extra heat and raises the efficiency potential above 90 percent. (High-efficiency systems are often referred to as “condensing” systems.)

To size a replacement system accurately, consider the home’s design-temperature heat loss, the room-by-room heat loss, and also the home’s existing radiation capacity. In situations of insufficient radiation capacity, the home may need more heat emitters in order to optimize the new system’s efficiency and to heat all rooms adequately.

With a high-efficiency boiler, the return water acts as coolant for the exhaust gases. The lower the temperature of the return water, the more the exhaust gases cool — which in turn increases the amount of water that condenses out of the exhaust, and thus increases the boiler’s efficiency. For this reason, lower return-water temperatures correlate with increased efficiencies.

Outside air temperature sensors are installed with a boiler to allow the boiler controls to sense the actual outside temperature. Outdoor reset is a control function that allows the boiler to adjust the supply-water temperature to the minimum needed to heat the building at a given outside temperature. When the boiler limits its heat output to the dwelling’s actual need, the lower supply-water temperature increases condensation and increases the boiler’s efficiency.

High-efficiency boilers require regular maintenance. Some high-efficiency boilers are especially vulnerable to problems with the distribution water — namely, dirt/debris/sediment/rust in the water and also an improper pH level, both of which can lead to plugged heat exchangers and other issues. Educate customers and make sure they understand the maintenance requirements.

Follow these additional instructions when installing high-efficiency boilers:

1. Verify that flue-gas oxygen and CO (or CO_2) are within the manufacturer’s ranges.
2. Equip the boiler with an outside air temperature sensor installed on a north-facing exterior wall.
3. Program the boiler’s heating curve (outdoor reset) in line with the dwelling’s heat loss and radiation capacity.
4. Setback thermostats are not recommended with boiler systems. This is because following the setback period, the boiler may need a long time to reheat the dwelling.

5. Ensure that the distribution water's pH level meets manufacturer's specifications.

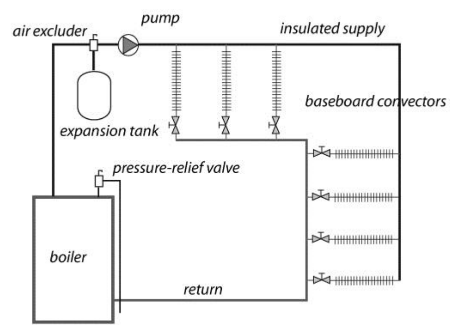
3.6 Hydronic Distribution Systems

Hydronic distribution systems consist of the supply and return piping, the circulator, expansion tank, air separator, air vents, and heat emitters. A properly designed and installed hydronic distribution system can operate for decades without service. Many systems, however, have installation flaws or need service.

Boiler piping and controls present many options for zoning, boiler staging, and energy-saving controls. Dividing homes into zones, with separate thermostats, can significantly improve energy efficiency over operating a single zone. Modern hydronic controls can provide different water temperatures to different zones with varying heating loads.

Follow these instructions for hydronic distribution systems:

1. Inspect radiators. Repair or replace as necessary.
2. Bleed air from radiators and from the entire system.
3. Confirm that the distribution system has no leaks.
4. Modify the distribution system as necessary to work properly with the replacement boiler.



Simple reverse-return hot-water system: The reverse-return method of piping is the simplest way of balancing flow among heat emitters.

5. The system shall have automatic and manual air-bleed valves to eliminate air from all high points in the distribution-piping system.
6. Extend new piping and radiators to conditioned areas, like additions and finished basements that currently are heated by space heaters.
7. Install thermostatically controlled radiator valves on the major radiators; or zone controls; or outdoor reset and boiler controls to adjust supply-water temperature according to outdoor temperature, if feasible for the boiler system.
8. Insulate all supply piping outside conditioned spaces. For hot-water systems, install 1½-inch fiberglass insulation on all pipes less than or equal to 1½ inches in diameter, and 2-inch fiberglass insulation on all pipes greater than 1½ inches in

Zone valves: Separate thermostats control each zone valve. Zone valves have switches that activate the burner.

diameter. For steam systems, install 1½-inch fiberglass insulation on all pipes less than or equal to 1½ inches in diameter, and 3-inch fiberglass insulation on all pipes greater than 1½-inch in diameter.

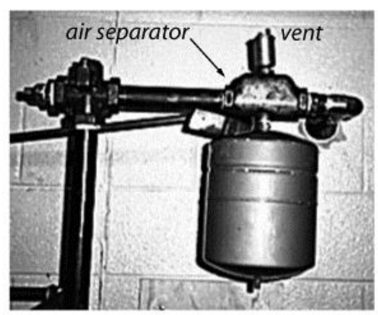
3.7 Boiler Efficiency and Maintenance

Boilers can maintain good performance and efficiency for many years if they are regularly maintained and tuned-up. Boiler performance and efficiency improve after effective maintenance and tune-up procedures.

Modern high-efficiency boilers require annual maintenance to achieve optimum performance and life expectancy. The most significant energy wasters in hot-water systems are poor steady-state efficiency, off-cycle flue losses robbing heat from stored water, and boilers operating at too high a water temperature. For information about boiler installation, see *Boiler Replacement in Chapter 3 - Section 3.5*.

Boiler performance and efficiency deteriorate in more ways than in forced-air furnaces. Specifically these are:

1. Corrosion, scaling, and dirt on the water side of the heat exchanger.
2. Corrosion, dust, and dirt on the fire side of the heat exchanger.
3. Excess air during combustion from air leaks and incorrect fuel-air mixture.
4. Off-cycle air circulation through the firebox and heat exchanger, removing heat from stored water.



Expansion tank, air separator, and vent: Preventing excessive pressure and eliminating air from the systems are important for hydronic distribution systems.

Consider the following maintenance and efficiency improvements for both hot-water and steam boilers:

1. Check for leaks on the boiler, around its fittings, or on any of the distribution piping connected to the boiler.
2. Clean noticeable dirt from the fire side of the heat exchanger.
3. Check doors and cleanout covers for air leakage. Replace gaskets, warped doors or warped cleanout covers.
4. Drain water from the boiler drain until the water flows clean.

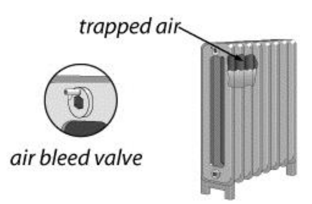
Safety Checks and Improvements

1. Confirm the existence of a 30-psi-rated pressure-relief valve. Replace a malfunctioning valve or add one if none exists. Note signs of leakage or discharges, and find out why the relief valve is discharging.
2. Make sure that the expansion tank isn't waterlogged or sized too small for the system. This could cause the pressure-relief valve to discharge. Test expansion tank for acceptable air pressure — usually 12 to 22 psi.

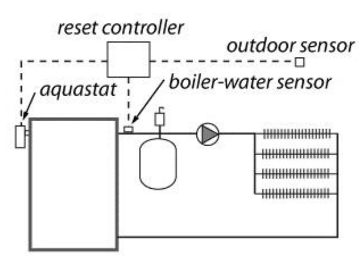
   Note: A hot-water boiler is recognized by its expansion tank, located somewhere above the boiler. The expansion tank provides an air cushion to allow the system's water to expand and contract as it is heated and cooled without creating excessive pressure in the boiler and piping and discharging through the pressure-relief valve.
3. If rust is observed in venting, verify that return water temperature is above 130° F for gas and above 150° F for oil, to prevent acidic condensation.
4. Verify the system does not cycle on high limit.
5. Lubricate circulator pump(s) if necessary.

Efficiency Improvements

1. Repair water leaks in the system.
2. Remove corrosion, dust, and dirt on the fire side of the heat exchanger.
3. Check for excess air during combustion from air leaks and incorrect fuel-air mixture.
4. Confirm that the boiler does not have low-limit control for maintaining a minimum boiler-water temperature, unless the boiler is heating domestic water in addition to space heating.
5. Bleed air from radiators and piping through air vents on piping or radiators.
6. Consider installing outdoor reset controllers on non-high efficiency boilers to regulate water temperature, depending on outdoor temperature.

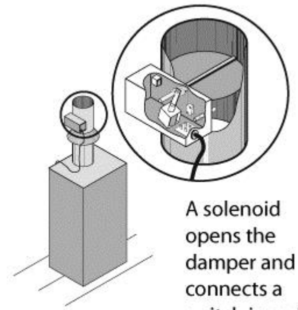


Purging air: Trapped air collects at the hot-water system's highest parts. Bleeding air from radiators fills the radiator and gives it more heating surface area.



Reset controller: The circulating-water temperature is controlled by the reset controller according to the outdoor temperature.

7. After control improvements like two-stage thermostats or reset controllers, verify that return-water temperature is high enough to prevent condensation and corrosion in the chimney as noted previously.
8. Consider installing a two-stage thermostat or timer control to increase circulator on-time as compared with burner on-time.
9. Vacuum and clean fins of fin-tube convectors if dust and dirt is present.
10. Consider installing electric vent dampers on natural-draft gas- and oil-fired high-mass boilers.



Vent dampers: Electric vent dampers close the chimney when the burner isn't firing, preventing circulating air from carrying the boiler's stored heat up the chimney.

3.8 Gas-Fired Heating Systems

3.8.1 Gas-Fired Heating-System Installation

The general procedures outlined in *General Heating-System Replacement in Chapter 3 - Section 3.2*, should be followed. Complete all tests on the Replacement Gas Furnace Check List and document results.

When replacing a gas-fired heating system:

1. Confirm that the clearances to nearby combustibles of the heating unit and its vent connector conform with NFPA 54.
2. Clock the gas meter if necessary to troubleshoot oxygen, flue-gas temperature, carbon-monoxide, or temperature-rise problems; and to verify that the actual gas input matches with the nameplate input rating. Adjust gas input if necessary. See *Measuring BTU Input on Natural-Gas Appliances in Chapter 3 - Section 3.8.3.*
3. Check the input gas pressure on the furnace when all gas-fired appliances are operating in the house to ensure no drop-off in required gas pressure. If the input is significantly different than the rating on the nameplate, all other variables above can be affected.
4. Measure manifold gas pressure to ensure that it stays within the manufacturer's specified range. Adjust the fuel-air mixture for the lowest CO output and maximum SSE.
5. Follow manufacturer's venting instructions, along with the International Fuel Gas Code (IFGC), to establish a proper venting system.

6. Follow manufacturer's instructions for proper removal of condensate. See *Condensate Removal in Chapter 3 - Section 3.8.2*.
7. Install a proper sediment trap on the gas line, if none exists.
8. When fuel-switching from oil to gas, place the old oil tank out of service in accordance with Wisconsin Administrative Code SPS 310.315.

3.8.2 Condensate Removal

High-efficiency heating systems have a primary heat exchanger and a secondary heat exchanger. Inside the secondary heat exchanger, water vapor in the furnace's exhaust condenses and thereby releases additional heat into the heating system. This release of heat is what allows the furnace to achieve an Annual Fuel Utilization Efficiency (AFUE) of 90+ percent.

When the exhaust gas condenses, water forms inside the secondary heat exchanger. The slightly acidic water, or ***condensate***, must be piped away from the furnace and to an appropriate drain.

Condensate is routed away from the furnace in one of two ways:

1) Running condensate tubing or piping directly from the furnace to an appropriate drain; or
2) Pumping the condensate from the furnace to an appropriate drain, using an electric ***condensate pump***.

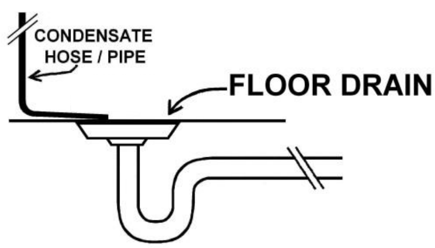
Whenever feasible, pipe directly from the furnace to the floor drain, without installing a condensate pump. Mechanically fasten the piping, either to the floor-drain strainer or to the floor itself.

Ensure that the piping will not pose a tripping hazard to the occupants. Installing a "trip strip", with the customer's approval, may be useful to prevent occupants from tripping over the piping.

Sometimes, a direct-piping strategy will not be feasible. There may not be a drain near the furnace, or perhaps the piping would pose a tripping hazard to the occupants. In these situations, installing a condensate pump is likely a better option. See the next section for information about condensate pumps.

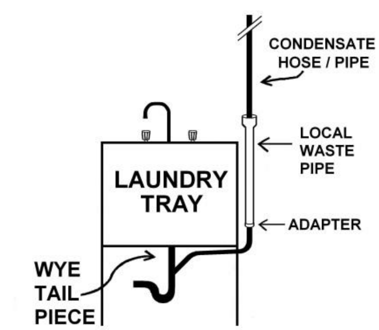
Condensate Pumps

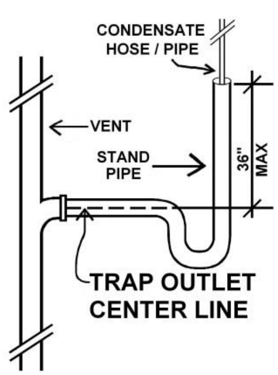
A condensate pump is installed when direct piping to an approved drain is not feasible. Condensate pumps may be installed using existing receptacles, new ground-fault circuit interrupter (GFCI) receptacles, or directly wired in accordance with pump manufacturer's requirements. Condensate is a slightly acidic byproduct of combustion. Building code requires that it be drained to the sanitary sewer system, and not to the ground or to a sump pump. The typical condensate receptors that code allows include a floor drain, a stand pipe, or an indirect or local waste pipe served by a stand pipe or the laundry tray tail piece. An air gap is required where the condensate line enters the receptor. The condensate line cannot be tapped and sealed directly into any drain pipe. See SPS 382.33 for Wisconsin code provisions regarding condensate drains.



Floor Drain – The floor drain is the most common method for discharging condensate. Condensate lines that run to the drain must be secured to the floor to keep them in place. This method works best when the drain is not in a typical path of foot traffic.

Stand Pipe – The laundry stand pipe is often the best place to discharge condensate. If the opening is not large enough for the washing machine hose and the condensate line, an adapter can be added to enlarge the top of the pipe. A stand pipe cannot exceed 36 inches in height above the centerline of the horizontal drain pipe. If an existing stand pipe is not an option, a new standpipe, trapped and vented, is acceptable. This option should be the last choice, as the trap can dry out if the heating system does not discharge condensate over an extended time period. If a washing machine could be discharged into the standpipe, extend the standpipe at least 18 inches above the centerline of the horizontal drain pipe.





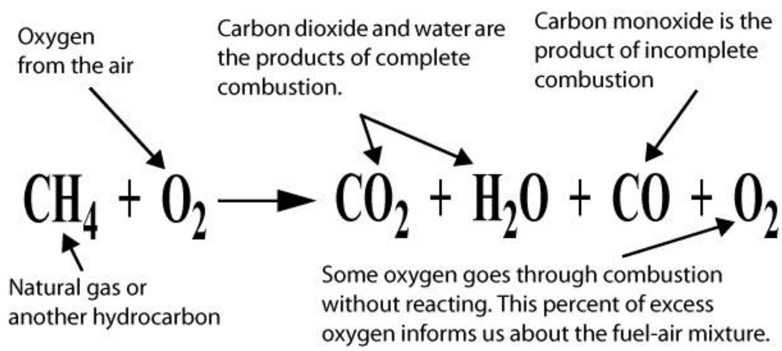
STAND PIPE

Indirect or Local Waste Pipe – A vertical pipe that uses the trap of a standpipe or laundry tailpiece is considered an indirect or local waste pipe. It needs to be higher than the flood line of the laundry tray or standpipe. This method can also be used if the existing standpipe is full of other hoses.

3.8.3 Testing and Servicing Gas-Fired Systems

Gas burners should be cleaned and tuned every two to four years. Sometimes a maintenance schedule will be posted on an existing heating system, allowing assessment of the heating-system maintenance history (or lack thereof).

The goals of these service measures are to reduce carbon monoxide (CO), to optimize fuel-air mixture, and to confirm the operation of safety controls. Complete all tests on the Heating System Repair or Clean and Tune Check List and document results.



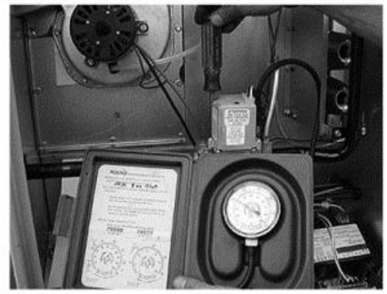
Perform the following inspection and maintenance procedures as necessary on gas-fired furnaces, boilers, water heaters, and space heaters:

1. Inspect for soot, melted wire insulation, melted grommets, and rust in the burner and manifold area outside the fire box. These all are indicators of flame rollout, combustion-gas spillage, and CO production.

Testing older furnaces: Insert the probe into the draft diverter near the exhaust ports of the heat exchanger.

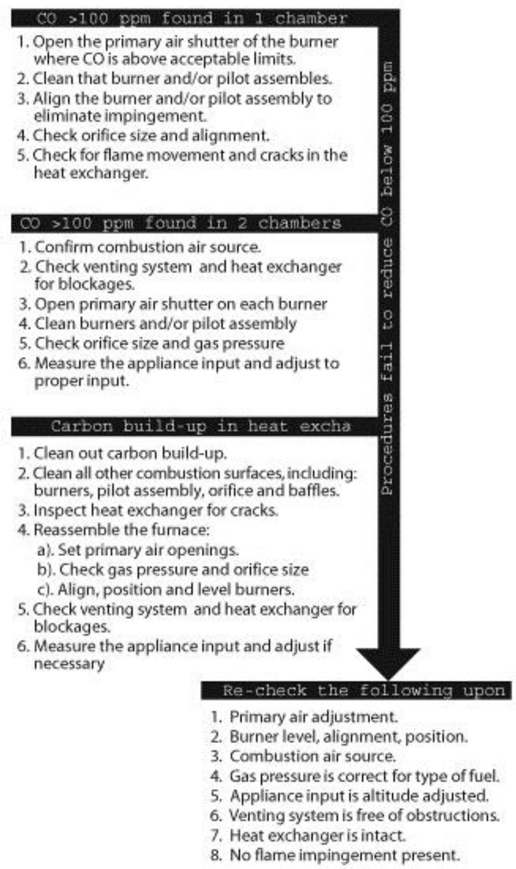
Testing 80+ furnaces Drill a quarter-inch hole in the metal vent connector to sample combustion gases.

2. Inspect the burners for dust, debris, misalignment, flame impingement, and other flame-interference problems. Clean, vacuum, and adjust as needed.
3. Inspect the heat exchanger for leaks.
4. Verify that heating system wiring connections are enclosed in covered electrical boxes.
5. Determine that the pilot is burning (if equipped) and that main burner ignition is satisfactory.
6. Sample the undiluted combustion gases with a calibrated flue-gas analyzer and record steady-state efficiency, O_2 percentage, CO ppm (as-measured), and flue-gas temperature.
7. Clock the natural-gas meter, with all other gas appliances off, to confirm that the input BTUs to the furnace or boiler match with the nameplate rating. Adjust gas pressure if necessary. See *Measuring BTU Input on Natural Gas Appliances in Chapter 3 – Section 3.8.3* for clocking the meter.
8. Clean the air handler ("squirrel cage") and the air-handler cabinet. Adjust the air handler's speed setting, if necessary, to ensure adequate airflow and to ensure that temperature rise is within the manufacturer's specifications.
9. Test pilot-safety control for complete gas-valve shutoff when pilot is extinguished.
10. When testing is complete, seal all test holes.
11. Verify that the thermostat's heat-anticipator setting matches the measured current in the 24-volt control circuit.
12. Check venting system for proper size and pitch.
13. Check venting system for obstructions, blockages, or leaks.
14. Measure chimney draft downstream of the draft diverter and check for spillage.
15. Measure gas input, and observe flame characteristics if soot, CO, or other combustion problems are present.

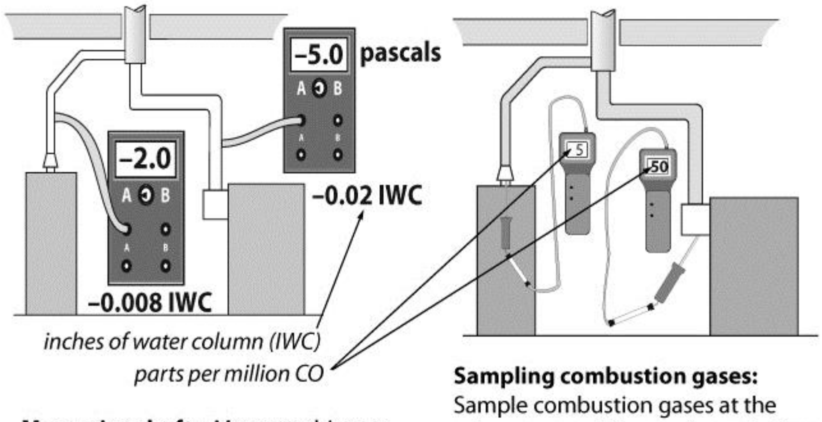


Adjusting gas pressure: Adjusting gas pressure is the only way to change the fuel-air mixture if testing shows that fuel-air mixture needs adjustment.

Troubleshooting CO



16. Open a window while testing for CO to see if CO is reduced by increasing combustion air.



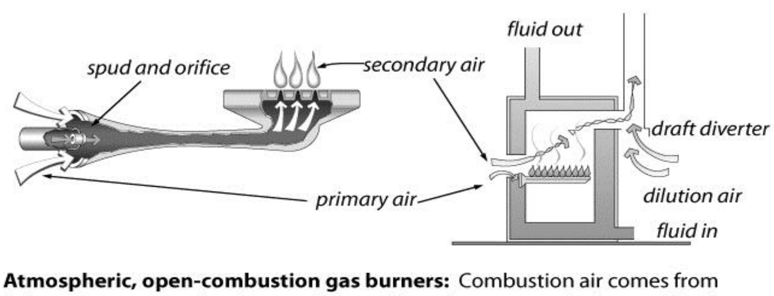
Measuring draft: Measure chimney draft *downstream* of the draft diverter.

Sampling combustion gases: Sample combustion gases at the exhaust vent of the appliance *before* dilution air mixes with the gases.

A common furnace-efficiency problem is low fuel input and high O_2 percentage, resulting in poor heat transfer. This condition will be detected by combustion testing and clocking the natural-gas meter. See the standards for O_2 percentage and flue-gas temperature in Table 3-2.

Flue-gas temperature is another important indicator of furnace performance. A low flue-gas temperature usually indicates efficient performance, since less of the heat is leaving the building. If the flue-gas temperature is too low in older furnaces or 80+ furnaces, however, acidic condensation will form in the vent. This acidic condensation can rust metal vents and damage masonry chimneys.

Adjust gas pressure and airflow in order to optimize gas input, O_2 percentage, flue-gas temperature and SSE. These adjustments are best made while monitoring the exhaust gas with the combustion analyzer.



Atmospheric, open-combustion gas burners: Combustion air comes from indoors in open-combustion appliances. These burners use the heat of the flame to pull combustion air into the burner. Dilution air, entering at the draft diverter, prevents over-fire draft from becoming excessive.

Table 3-2: Typical Ranges for Gas Burning Appliances

Performance Indicator	SSE 80+	SSE 90+
Carbon monoxide (CO) (ppm)	≤ 100	≤ 100
Stack temperature (°F)	325° - 450°	90° - 120°
Temperature Heat rise (°F)	40° - 70°	30° - 70°
Oxygen (O_2)	4-9%	4-9%
Gas pressure output at manifold - Inches of Water Column (IWC)	3.2 – 3.9	3.2 – 3.9
Propane pressure output at manifold (IWC)	10 – 11	10 – 11
Steady state efficiency (SSE)	82 – 86%	92 – 97%
Supply temperature (°F)	120° - 140°	95° - 140°

Proceed with burner maintenance and adjustment when any of the following are present:

1. CO is greater than 100 ppm as measured or 200 ppm air-free;
2. Visual indicators of soot or flame roll-out exist;
3. Burners are visibly dirty;
4. Measured draft is inadequate;

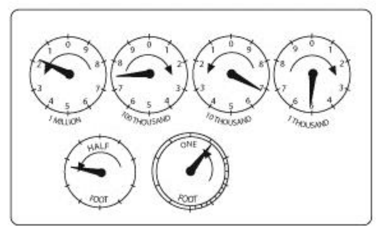
Table 3-3: Combustion Problems and Possible Solutions

Problem	Possible causes and solutions
Weak draft with CAZ depressurization	Return duct leaks, clothes dryer, exhaust fans, other chimneys. Seal return leaks. Provide make-up air.
Weak draft with no CAZ depressurization	Chimney blocked or leaky or else CAZ is too airtight.
Carbon monoxide	Mixture too rich or too lean. Adjust gas pressure. Check chimney and combustion air for code compliance.
Stack temperature or heat rise too high or low	Adjust fan speed or gas pressure. Improve ducts to increase airflow.
Oxygen too high or low	Adjust gas pressure, but don’t increase CO level.

Gas-burner maintenance includes the following measures:

1. Remedy the causes of CO and soot. These causes may include over-firing, closed primary air intake, flame impingement, and lack of combustion air.
2. Remove dirt, rust, and other debris that may be interfering with the burners. Clean the heat exchanger, if necessary.
3. Take action to improve draft, if inadequate because of improper venting, obstructed chimney, leaky chimney, or depressurization. See *Improving Inadequate Draft in Chapter 3 - Section 3.13.1.*
4. Seal leaks in vent connectors and chimneys.
5. Adjust gas input if combustion testing or clocking the gas meter indicates over-firing or under-firing.

Measuring BTU Input on Natural-Gas Appliances



Gas meter dial: Use the number of seconds per revolution of the one-foot dial and the table on the following page to find the appliance's input.

1. Turn on the appliance to test, and then turn off all other gas-combustion appliances (such as heating systems, water heaters, dryers, cook stoves, space heaters, etc.) that are connected to the meter being timed.
2. Fire the appliance being tested, and watch the dials of the gas meter.
3. Carefully count how long it takes for one revolution of the 1/2-, 1-, or 2-cubic-foot dial. Find that number of seconds in the columns marked "Seconds per Revolution" in *Table 3-4*. Follow that row across to the right to the correct column for the 1/2-, 1-, or 2-cubic foot dial. Multiply the number in the table by 1,000. Record the input in thousands of BTUs per hour. *For gauging a 1/4-cubic-foot dial, count how long it takes for 4 revolutions. Then, use the 1-cubic-foot column to determine the input.*
4. If the measured input is higher or lower than input on the nameplate by more than 10%, adjust gas pressure up or down, within the ranges in *Table 3-3* on until the approximately correct input is achieved.
5. For LP gas, determine the orifice size. From Table E.1.1 of the National Fuel Gas Code, find the input BTU value that corresponds with the orifice size. Multiply the listed BTU value by the number of orifices to get the input BTU for the heating system.
6. If the measured input is still out of range after adjusting gas pressure to these limits, replace the existing orifices with larger or smaller orifices sized to give the correct input. Any changes done to orifices must follow manufacturer's instructions.

Table 3-4: Input in thousands of Btu/hr for 1000 Btu/cu. ft. gas

Seconds per Revolution	Size of Meter Dial			Seconds per Revolution	Size of Meter Dial			Seconds per Revolution	Size of Meter Dial		
	½ cu. ft.	1 cu. ft.	2 cu. ft.		½ cu. ft.	1 cu. ft.	2 cu. ft.		½ cu. ft.	1 cu. ft.	2 cu. ft.
15	120	240	480	40	45	90	180	70	26	51	103
16	112	225	450	41	44	88	176	72	25	50	100
17	106	212	424	42	43	86	172	74	24	48	97
18	100	200	400	43	42	84	167	76	24	47	95
19	95	189	379	44	41	82	164	78	23	46	92
20	90	180	360	45	40	80	160	80	22	45	90
21	86	171	343	46	39	78	157	82	22	44	88
22	82	164	327	47	38	77	153	84	21	43	86
23	78	157	313	48	37	75	150	86	21	42	84
24	75	150	300	49	37	73	147	88	20	41	82
25	72	144	288	50	36	72	144	90	20	40	80
26	69	138	277	51	35	71	141	94	19	38	76
27	67	133	267	52	35	69	138	98	18	37	74
28	64	129	257	53	34	68	136	100	18	36	72
29	62	124	248	54	33	67	133	104	17	35	69
30	60	120	240	55	33	65	131	108	17	33	67
31	58	116	232	56	32	64	129	112	16	32	64
32	56	113	225	57	32	63	126	116	15	31	62
33	55	109	218	58	31	62	124	120	15	30	60
34	53	106	212	59	30	61	122	130	14	28	55
35	51	103	206	60	30	60	120	140	13	26	51
36	50	100	200	62	29	58	116	150	12	24	48
37	49	97	195	64	29	56	112	160	11	22	45
38	47	95	189	66	29	54	109	170	11	21	42
39	46	92	185	68	28	53	106	180	10	20	40

3.8.4 Leak-Testing Gas Piping

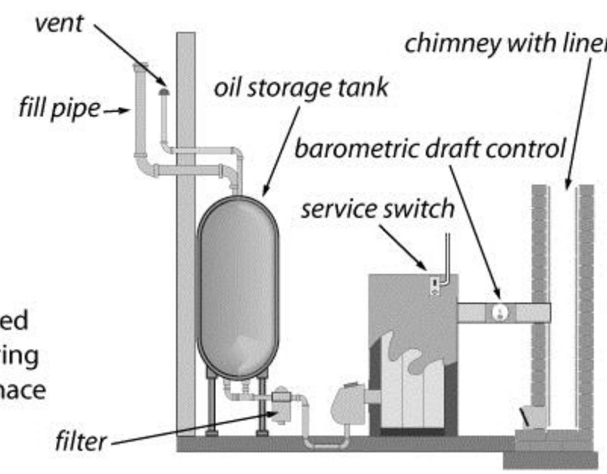
For information on leak-testing gas piping, see *Leak-Testing Gas Piping in Chapter 5 – Section 5.3.5*.

3.9 Oil-Fired Heating Systems

3.9.1 Oil-Fired Heating-System Installation

The general procedures outlined in *General Heating System Replacement in Chapter 3 - Section 3.2* should be followed when replacing an oil heating system. Complete all tests on the Oil Replacement Furnace Check List and document results.

Oil heating system: Components of an oil heating system may need repair and cleaning during replacement of the furnace or boiler.



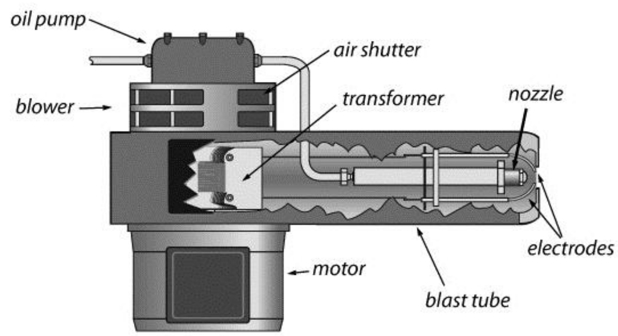
When replacing an oil furnace:

1. Properly size the nozzle based on the post-weatherization conditions, using REScheck®, Manual J, or an equivalent industry-accepted sizing formula. Document the nozzle size on the inside of the furnace cabinet, next to the furnace nameplate.
2. Examine the existing chimney and vent connector for suitability as venting for the new appliance. The vent connector may need to be resized, and the chimney may need to be relined.
3. Confirm that the clearances to nearby combustibles of the heating unit and its vent connector conform with NFPA 31.
4. Test oil pressure, and verify that it complies with manufacturer's specifications.
5. Test control circuit amperage, and adjust the thermostat's heat anticipator to match.
6. Test smoke number to confirm that it meets manufacturer's specifications. See *Table 3-5*.

7. Install a new fuel filter, and purge the fuel lines.
8. Verify that the chimney operates safely and in accordance with NFPA 211.
9. Confirm that the tank and oil lines comply with NFPA 31.

3.9.2 Testing and Servicing Oil-Fired Systems

Oil burners require annual maintenance to retain their operational safety and combustion efficiency. Testing for steady-state efficiency, draft, carbon monoxide, and smoke should be used to guide and evaluate maintenance. These clean-and-tune procedures pertain to oil-fired furnaces, boilers, and water heaters.



Oil burner: Performance and efficiency will deteriorate over time if neglected. Annual maintenance is recommended.

Oil-Burner Inspection and Testing

Evaluate oil-burner operation by visually inspecting and combustion-testing the system. An oil burner passing visual inspection and giving good test results may need minimal maintenance. If the test results are fair, adjustments may be necessary. Unsatisfactory test results may indicate the need to replace the burner or the entire heating unit.

Follow these steps to improve oil-burner safety and efficiency:

1. Inspect burner and appliance for signs of soot, overheating, fire hazards, corrosion, or wiring problems.
2. Equip all oil-fired heating systems with a barometric draft control, unless the system has high-static burners.
3. Confirm that the oil heating system has a dedicated electrical circuit.
4. Enclose all 120-volt wiring connections in covered electrical boxes.
5. Inspect fuel lines and storage tanks for leaks.
6. Inspect heat exchanger and combustion chamber for cracks, corrosion, or soot buildup.
7. Check to see if flame ignition is instantaneous or delayed. Flame ignition should be instantaneous, except for pre-purge units where the blower runs for a while before ignition.

8. Sample undiluted flue gases with a smoke tester, following the smoke-tester instructions. Compare the smoke smudge left by the gases on the filter paper with the manufacturer's smoke-spot scale to determine smoke number. ***With a smoke number of Two or higher, do not use the electronic combustion analyzer.***
9. Analyze the flue gas for O_2 percentage, temperature, CO ppm, and steady-state efficiency (SSE). Sample undiluted flue gases between the barometric draft control and the appliance. Adjust fuel-air mixture and airflow to conform to standards in Table 3-5.
10. Measure flue draft between the appliance and barometric draft control and over-fire draft over the fire inside the firebox.
11. Measure high-limit shut-off temperature, and adjust or replace the high-limit control if the shut-off temperature is more than 250°F for furnaces or 180°F for hot-water boilers.
12. Measure oil-pump pressure, and adjust to manufacturer's specifications if necessary.
13. Measure transformer voltage, and replace transformer if not within the allowable range.
14. Ensure that barometric draft controls are mounted plumb and level, and that the damper swings freely.
15. Time the cad cell control or stack control to verify that the burner will shut off, within the time frame per manufacturer's specifications, when the cad cell is blocked from seeing the flame.

Table 3-5: Typical Ranges for Oil Burning Appliances

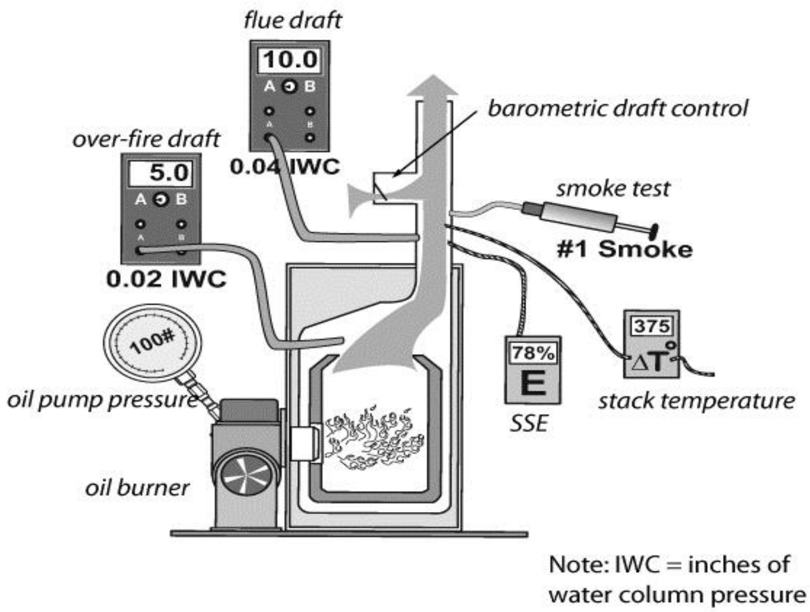
Performance Indicator	Non-Flame Retention	Flame Retention
Carbon monoxide (CO) (ppm)	≤ 100	≤ 100
Stack temperature (°F)	325° - 550°	300° - 450°
Oxygen (O_2)	6-9%	5-9%
Smoke number (1-9)	≤ 2	≤ 1
Excess air (%)	≥ 80%	≥ 35%
Oil pressure pounds per square inch (psi)	≥ 100	100 -150
Over-fire draft (Inches of Water Column - IWC negative)	.02 IWC or 5 Pa	.02 IWC or 5 Pa
Flue draft (IWC negative)	.04 -.01 IWC or 10-15 Pa.	04 -.01 IWC or 10-15 Pa.
Steady state efficiency (SSE)	≥ 75%	≥ 80%

Oil-Burner Maintenance and Adjustment

After evaluating the oil burner's initial operation, perform the following maintenance tasks as needed to optimize safety and efficiency:

1. Verify correct flame-sensor operation.
2. Replace burner nozzle after matching the new nozzle's size to the home's post-weatherization heat-load requirements.

3. Clean the burner's blower wheel.
4. Replace oil filter(s).
5. Clean or replace air filter. See "*Filters" in Section 3.4.6* for guidance on providing furnace filters.
6. Remove soot and sludge from combustion chamber.



Measuring oil-burner performance: To measure oil-burning performance indicators, a manometer, flue-gas analyzer, smoke tester, and pressure gauge are required.

7. Remove soot from heat-exchange surfaces.
8. Clean dust, dirt, and grease from the burner assembly.
9. Ensure that the oil pump is set to the correct pressure.
10. Adjust air shutter to achieve O_2 and smoke values, specified in Table 3-5.
11. Adjust barometric damper for a negative flue draft of 10–15 pascals or 0.04-to-0.06 IWC (before barometric damper).
12. Adjust gap between electrodes and their position in burner tube, per manufacturer's specifications.
13. Repair the ceramic combustion chamber, or replace it if necessary.
14. Inspect and clean end of the burner-tube assembly. Replace flame-retention head if damaged.

15. Inspect and clean transformer contacts to remove any corrosion.

After these maintenance procedures, perform the diagnostic tests described previously to evaluate improvement made by the maintenance procedures and to determine if fine-tuning is required.

3.10 Electric Furnaces and Electric Baseboard Heat

In Wisconsin, electric baseboard heat is much more common than electric furnaces. Due to the high cost of electricity, these systems may be good candidates for fuel-switching.

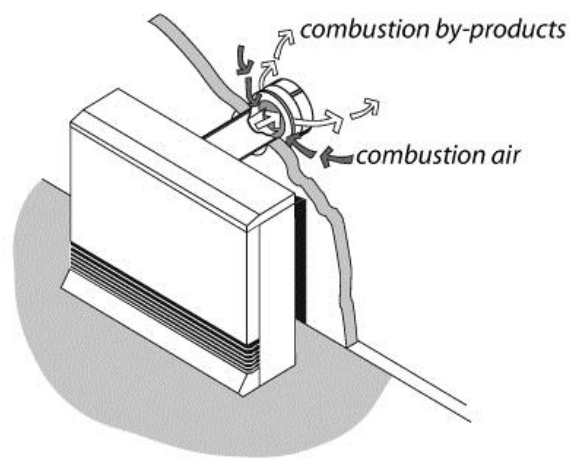
Caution: Disconnect power from electric furnaces before performing any maintenance.

1. Check or clean and lubricate the following components: thermostat, blower, housing around electric element, baseboard fins.
2. Clean or replace all filters.
3. Take extra care in duct sealing and in duct-airflow improvements for electric furnaces because of the high cost of electricity.
4. Verify that safety limits and temperature rise conform to manufacturer's specifications.

3.11 Replacing Space Heaters

When replacing a space heater:

1. Follow manufacturer's venting instructions carefully. Don't vent sealed-combustion, induced-draft space heaters into naturally drafting chimneys.
2. If the space heater will sit on a carpeted floor, provide a fire-rated floor protector, sized to the width and length of the space heater, as a base.
3. Locate space heater away from traffic, draperies, and furniture.
4. Space heaters require a properly grounded duplex receptacle for electrical service.



Sealed combustion space heater: Sealed combustion space heaters draw combustion air in and exhaust combustion by-products, using a draft fan.

Inform the client of the following operating instructions:

1. Don't store any objects near the space heater that would restrict airflow around it.
2. Don't use the space heater to dry clothes or for any purpose other than heating the home.
3. Don't allow anyone to lean or sit on the space heater.
4. Don't spray aerosols near the space heater. Many aerosols are flammable or can cause corrosion to the space heater's heat exchanger.

Space heater controls: Many modern energy-efficient space heaters have programmable thermostats as standard

3.12 Replacing Wood Stoves

Wood stoves that have a crack or hole in the fire box should be replaced. Units that do not meet clearances and cannot be corrected should be considered for replacement. All replacement wood stoves must meet applicable local codes and EPA requirements. Installations must conform to the NFPA 211.

When replacing a wood stove:

1. Install the stove to meet manufacturer's specifications.
2. Verify that the replacement stove is certified to meet EPA emission standards or local standards, whichever are stricter.
3. Confirm that the installed unit is certified and labeled by:
   a. National Fire Protection Association under 211-1996; or
   b. International Conference of Building Officials; or
   c. Other equivalent listing organization.
4. Visually inspect the chimney for safe operation by referring to NFPA 211.
5. Provide all clients with in-home operation instructions, to include proper wood-burning practices; safety information; and education about proper maintenance, such as stack thermometers and the need for fire extinguishers.
6. Educate the customers about the potential impact of exhaust ventilation and/or forced-air distribution on the wood heater's operation.
7. Install make-up air if the building is tightened below the Depressurization Limit CFM_{50}.

3.13 Venting Combustion Gases

Proper venting is essential to the operation, efficiency, safety and durability of combustion heaters. The National Fire Protection Association (NFPA) and the International Code Council (ICC) are the authorities on material-choice, sizing, and clearances for chimneys and vent connectors, as well as for combustion air. The information in this venting section is based on the following NFPA and ICC documents:

- ✓ The International Fuel Gas Code (IFGC) (ICC)
- ✓ NFPA 31: Standard for the Installation of Oil-Burning Equipment
- ✓ NFPA 211: Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel- Burning Appliances

Table 3-6: Guide to Venting Standards

Topic	Code Reference
Venting Sizing	IFGC, Section 504
Clearances	IFGC, Section 308 and Tables 308.2l NFPA 31, Section 4-4.1.1 and Tables 4-4.1.1 and 4-4.1.2 NFPA 211, Sections 6.5, 4.3, 5
Combustion Air	IFGC, Section 304 NFPA 31, Section 1-9; NFPA 211, Section 8.5 and 9.3

3.13.1 Improving Inadequate Draft

If measured draft is below the minimum worst-case requirement, investigate the reason for the weak draft. Open a nearby window, exterior door, or interior door to observe whether the addition of make-up air will improve draft. If the added air strengthens draft, then the problem usually is depressurization. If opening a window has no effect, inspect the chimney. The chimney could be blocked or excessively leaky.

Chimney Improvements to Solve Draft Problems

Consider the following chimney improvements when attempting to improve worst-case draft:

1. Remove chimney obstructions.
2. Repair disconnections or leaks at joints and where the vent connector joins a masonry chimney.

3. Measure the size of the vent connector and chimney and compare with vent-sizing information listed in Section 504 of the International Fuel Gas Code. A vent connector or chimney liner that is either too large or too small can result in poor draft.
4. Increase the pitch of horizontal sections of vent, to facilitate the flue gases' movement toward the chimney.
5. Extend the flue's roof-jack. This option may be especially useful when the appliance's exhaust stack is short — for example, in a mobile home, or in a ranch home on a slab.
6. If wind is causing erratic draft, consider installing a wind-dampening chimney cap.

If the masonry chimney is deteriorated, consider installing a new chimney liner.

Duct Improvements to Solve Draft Problems

Consider the following duct and airflow improvements when attempt to improve worst-case draft:

1. Seal/remove any return grilles in the CAZ.
2. Install a sealing filter cover.
3. Seal return-duct leaks in the CAZ, using the diagnostic workbook to guide duct-sealing decision-making.
4. Isolate the furnace from its return registers by air-sealing.
5. Install make-up air to the CAZ. Open a nearby window, exterior door, or interior door to observe whether the addition of make-up air will improve draft. If the open window or door improves draft to an acceptable level, measure the size of the opening, and install make-up air accordingly.

Table 3-7: Draft Problems and Solutions

Problem	Possible Solutions
Adequate draft never established	Remove chimney blockage, seal chimney air leaks, or provide additional combustion air as necessary.
Blower activation weakens draft	Seal leaks in the furnace and in nearby return ducts. Isolate the furnace from nearby return registers.
Exhaust fans weakens draft	Provide make-up or combustion air if opening a door or window to outdoors strengthens draft during testing.
Closing interior doors during blower operation weakens draft	Add return ducts, grills between rooms, or jumper ducts.

3.14 Combustion Air

A combustion-appliance zone (CAZ) is classified as either an ***unconfined space*** or as a ***confined space***. An unconfined space is a CAZ connected to enough building air leakage to provide combustion air. A confined space is a CAZ with sheeted walls and ceiling and a closed door that form an air barrier between the appliance and other indoor spaces.

Table 3-8: CFM Air Requirements for Combustion Furnaces or Boilers

Appliance	Combustion Air (cfm)	Dilution Air (cfm)
Conventional Oil	38	195
Flame-Retention Oil	25	195
High-Efficiency Oil	22	-
Conventional Atmospheric Gas	30	143
Fan-Assisted Gas	26	-
Condensing Gas	17	-
Fireplace (no doors)	100-600	-
Airtight Wood Stove	10-50	
A.C.S. Hayden, Residential Combustion Appliances: Venting and Indoor Air Quality Solid Fuels Encyclopedia		

For confined spaces, the IFGC prescribes additional combustion air from outside the CAZ. Combustion air is supplied to the combustion-appliance zone in four ways.

1. To an unconfined space through leaks within the building.
2. To a confined space through an intentional opening or openings between the CAZ and other indoor areas where air transfers in to replenish combustion air.
3. To a confined space through an intentional opening or openings between the CAZ and outdoors or ventilated intermediate zones like attics and crawl spaces.
4. Directly from the outdoors to the confined or airtight CAZ through a duct. Appliances with their own direct combustion-air ducts are called ***sealed-combustion*** or ***direct-vent*** appliances.

3.14.1 Unconfined-Space Combustion Air

Combustion appliances located in most basements, attics, and crawl spaces get adequate combustion air from leaks in the building shell. Even when a combustion appliance is located within the home's living space, it usually gets adequate combustion air from air leaks, unless the house is airtight or the combustion zone is depressurized.

3.14.2 Confined-Space Combustion Air

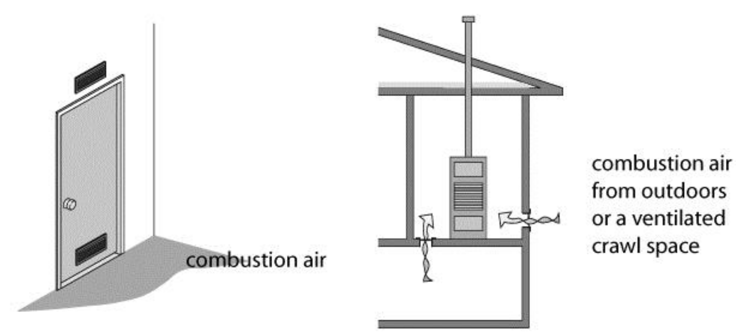
A confined space is defined by the IFGC as a room that contains one or more combustion appliances and which has less than 50 cubic feet of volume for every 1,000 BTUs per hour (BTUh) of appliance input.

If a small mechanical room is connected to adjacent spaces through large air passages like floor-joist spaces, however, the CAZ may not need additional combustion air, even with sheeted walls and a door separating it from other indoor spaces. The extent of the connection between the CAZ and other spaces can be confirmed by worst-case draft testing or blower-door testing.

On the other hand, if the home is unusually airtight, the CAZ may not be able to obtain adequate combustion air, even when the CAZ is larger than the minimum confined-space room volume, defined above.

In confined spaces or airtight homes where outdoor combustion air is needed, the best strategy is a single vent opening installed as low in the CAZ as is practical. A combustion-air vent into an attic may depressurize the combustion zone or dump warm, moist air into the attic. Instead, connect the combustion zone directly to the outdoors or to a ventilated crawl space through a single low vent, if possible.

Choose an outdoor location that is sheltered, where the wall containing the vent isn't parallel to prevailing winds. Wind blowing parallel to an exterior wall or at a right angle to the vent opening tends to de-pressurize both the opening and the CAZ connected to it. Indoors, locate combustion air vents away from water pipes to prevent the pipes from freezing.



Passive combustion-air options: Combustion air can be supplied from adjacent indoor spaces or from outdoors. Beware of passive combustion-air vents into the attic that could depressurize the combustion zone or allow moist indoor air to travel into the attic.

3.14.3 Net Free Area

Net free area is the surface area of venting that remains open after subtracting for the blocking effect of louvers and grilles. Metal grilles and louvers are assumed to reduce the size of the vent opening to 75 percent of the original surface area. Wooden grilles and louvers are more restrictive, and they are assumed to reduce the net free area to 25 percent of the original surface area.

Manufacturers often provide specifications about the net free area through their grilles and louvers. When this information is available, use it to calculate the size of opening required to provide the net free area necessary. When these specifications are not available, use the assumptions listed above.

For example, calculate a 10-inch by 10-inch opening (100 square inches) with a metal grille attached as having 75 square inches of net free area. With a wooden louver installed, to calculate the same opening use 25 square inches of net free area.

When sizing vent openings always account for the reduction in net free area that will occur due to the installation of grilles and louvers.

3.14.4 Sizing Combustion-Air Openings

Table 3-9 summarizes the required ratios of combustion-air net free area to appliance input (BTUh).

Table 3-9: Combustion Air Openings: Location and Size

Location	Dimensions
Two direct openings to adjacent indoor space	Minimum area each: 100 in^2 1 in^2 per 1000 Btuh each Combined rooms volumes must be ≥S 50 ft^3/1000 Btuh
Two direct openings or vertical ducts to outdoors	Each vent should have 1 in^2 for each 4000 Btuh
Two horizontal ducts to outdoors	Each vent should have 1 in^2 for each 2000 Btuh
Single direct or ducted vent to outdoors	Single vent should have 1 in^2 for each 3000 Btuh
From the *International Fuel Gas Code (IFCG)*	

Here is an example of sizing two direct combustion-air openings to adjacent indoor space: The furnace and water heater are located in a confined space. The furnace has an input rating of 100,000 BTUh. The water heater has an input rating of 50,000 BTUh. Combined, the two appliances have an input rating of 150,000 BTUh. So, each opening must have at least 150 square inches of net free area of venting between the mechanical room and adjacent indoor space (150,000 ÷ 1,000 = 150). There are two openings, so the CAZ will have a total of 300 square inches of net free area of venting.

If the same CAZ were ducted to the outdoors with a single opening, the requirement for net free area of venting would decrease to 50 square inches (150,000 ÷ 3,000 = 50 sq. in.).

When installing two combustion-air openings, the IFGC usually requires that one opening commences 12 inches from the ceiling and one opening 12 inches from the floor. See *IFGC 2012, Section 304.5* for a full breakdown of combustion-air requirements.

3.15 Thermostats

Set the thermostat's heat anticipator to the amperage measured in the control circuit, or follow the thermostat-manufacturer's instructions for adjusting cycle length.

3.15.1 Programmable Thermostats

A programmable thermostat may be a big energy saver if the occupants understand how to operate the thermostat. If the existing thermostat will be replaced as a part of the weatherization work, discuss this option with the occupant. If the occupant is willing to use a programmable thermostat, proceed with the installation. Educate the occupant on the use of the thermostat, and leave a copy of manufacturer's directions with them.

Final inspection and Quality Assurance Standards

Heating system work shall meet the following requirements.

Required Outcomes		
	Replacements	**Clean and Tune**
All Fuels & Types	1. The carbon monoxide concentration in the undiluted flue gas does not exceed 100 ppm as-measured or 200 ppm air-free, unless manufacturer's specification limit is higher.	1. The carbon monoxide concentration in the undiluted flue gas does not exceed 100 ppm as-measured or 200 ppm air-free, unless manufacturer's specification limit is higher.
Gas Systems	2. Test and set the gas pressure within the manufacturer's specifications.	2. Test and set the gas pressure within the manufacturer's specifications
Oil Systems	3. The smoke test: ≤ 1 for flame retention burner systems and ≤ 2 for non-flame retention burner systems using a smoke-spot scale	3. The smoke test: ≤1 for flame retention burner systems and ≤2 for non-flame retention burner systems using a smoke-spot scale.
Forced-Air	4. The temperature rise is within the manufacturer's specification.	4. The temperature rise is within the manufacturer's specification.
All Boilers	5. O_2 and CO (or CO_2) values are within manufacturer's specified range. 6. Non-condensing boiler: The stack temperature is at least 300 degrees to minimize condensation in the chimney.	5. O_2 and CO (or CO_2) values are within manufacturer's specified range. 6. Non-condensing boiler: The stack temperature is at least 300 degrees to minimize condensation in the chimney.
≥ 90% Boilers	7. Outside air temperature sensor is installed on a north-facing exterior wall. 8. Heating curve is programmed in line with the dwelling's heat loss and radiation capacity.	7. Outside air temperature sensor is installed on a north-facing exterior wall. 8. Heating curve is programmed in line with the dwelling's heat loss and radiation capacity.

Heating Systems - General

1. Heating System Check List is complete, in file;
2. Condensate:
    a. Properly drains and is secured to floor drain
    b. Does not present a tripping hazard.
    c. Pump installed only when needed.
3. No fuel leaks.
4. Oil systems have a new oil filter.
5. There are no pre-existing unvented space heaters remaining in place.

Required Testing		
	Replacements	**Clean and Tune**
All Fuels & Types	1. Measure the steady-state efficiency (SSE).	1. Measure the steady-state efficiency (SSE).
All Fuels & Types	2. Measure oxygen (O_2) levels. See Table 3-2, Typical Ranges for Gas-Burning Equipment.	2. Measure oxygen (O_2) levels. See Table 3-2, Typical Ranges for Gas-Burning Equipment.
All Fuels & Types	3. Measure the stack temperature (T-Stack).	3. Measure the stack temperature (T-Stack).
Forced-Air	4. Measure the air flow of the furnace air handler. Use a flow plate or the manufacturer's fan-flow tables to calculate air flow.	4. Measure the air flow of the furnace air handler. Use a flow plate or the manufacturer's fan-flow tables to calculate air flow.
All Boilers	5. Measure the supply and return water temperatures.	5. Measure the supply and return water temperatures.

New Heating Systems

1. Heating system is properly sized and adequately heats the building.
   a. Sizing calculation is in the customer file that accurately reflects the heat loss of the post-weatherization building.
   b. Distribution system is adequate for the properly sized furnace.
2. Heating system has proper venting.
   a. Meets manufacturer's and code requirements.
   b. Proper clearances from windows and doors
3. System is raised off of the floor by durable materials.
   a. For basements with known water problems, the height is based on typical high water marks noted in the CAZ or based on customer input.
4. Heating system equipment meets specification requirements.
5. Building permit obtained as required.
6. Installation meets code requirements.
7. System is on a dedicated electrical circuit.
   a. Service disconnect is present or within line-of-sight at service panel.
   b. Circuit is properly sized or a fuse or breaker is installed to protect the system.
8. The warranty and/or manual booklet is posted on or near the furnace.
9. Installed wood systems or stoves comply with NFPA 211 or EPA (per label).

Forced-Air Distribution

1. Filter/compartment
   a. is properly sealed, tight cover fit, and the filter seals to the filter rack.
   b. allows for easy filter replacement.
   c. Filter is MERV 6 or better.
   d. 1 cleanable filter or 6 disposable filters included.
2. Distribution within the CAZ and living areas are sealed based on worst-case depressurization testing. The distribution system does not excessively depressurize the CAZ, (>1 Pascal, based on warnings in the diagnostic workbook when Category I appliances are present) circulate unhealthy air into the living area, and does provide adequate heat and return air to the living areas.

3. Supplies heat to the assigned rooms in an efficient and sufficient manner
4. New supply and return ducts are the proper size for efficient operation of the heating system.
5. Duct joints are properly attached.
6. Metal ducts were sealed with a UL181 rated material.
7. Distribution work in unheated areas is insulated to minimum of R-10.
8. Insulation meets material specifications and is not compressed.
9. Fiberglass insulation is installed with mechanical fasteners.
10. Registers are properly functioning for their intended purpose.
11. There are no return grills in the CAZ.
12. New supply ducts have dampers.
13. Mobile home return air system is centralized through living space
14. Back-draft dampers have been installed between a wood furnace plenum and another forced air system.

Boilers

1. Boiler size is properly calculated and includes domestic hot water when applicable.
2. Existing radiators and other terminal devices are the appropriate size and quantity for the spaces they heat.
3. Heating System Check List is complete, in file;
4. Replacement units must be rated for the application.
5. The existing feed water and distribution systems was modified as necessary to work properly with a new boiler, including boiler controls, auto fill valve, zone valve, expansion tank is present and functioning as designed, and air temperature sensor is installed.
6. Existing boiler or distribution was properly adjusted or modified.
7. Radiators were bled and there no air is in the system.
8. Pressure relief valve has been documented as opened; closes without leaking,
9. (3 and 4 unit buildings only) Boiler registration number is posted with current state certified inspection.

Hot-Water Space-Heating Distribution

1. Pipes are insulated in unheated areas.
2. Seams are tightly fitted and secured.
3. No leaks in the system.

Thermostats

1. Installed thermostat functions properly with the installed heating system and meets household needs.
2. Customer has been educated and understands how to operate programmable thermostat.
3. Thermostat is in a location that allows the heating system to operate properly and heat the space.
4. Thermostat is installed on an interior wall.

Additional Considerations

Under certain circumstances the following items may be necessary to verify that other tests results are correct or for troubleshooting various problems.

1. Air flow through the flow meter is consistent with flow rate listed in Table 3.1 and the manufacturer's fan tables.

Additional Tests		
	Replacements	**Clean and Tune**
All Fuels & Types	1. Confirm that excess air (EA) is adequate.	1. Confirm that excess air (EA) is adequate.
Nat Gas Systems	2. Measure the input by “clocking the meter” to determine the input of a natural gas appliance. Input is typically within 10% of the appliance rating.	2. Measure the input by “clocking the meter” to determine the input of a natural gas appliance. Input is typically within 10% of the appliance rating.
Oil Systems	3. Check oil pump pressure.	3. Check oil pump pressure.
Forced -Air	4. Measure external static pressure (ESP).	4. Measure external static pressure (ESP).